The nucleus for a good Mexican collection has been made, and there are exhibited collections illustrating the culture of several of the civilized tribes of ancient Mexico, the Nahuas, the Zapotecas, Mixtecas, the Mayas, and Tarascos. In northern Mexico the expedition under Dr. Lumholtz has given the Museum a most complete collection of the ceramic art of the old Pueblo stock of Casas Grandes in Chihuahua. In our own country a recent acquisition is that of the Hyde collection of antiquities from the cliff dwellings and ancient pueblos of New Mexico and southern Colorado. This collection will be largely increased by the exploration of ancient pueblos carried on by the Messrs. Hyde during the present year.

There is on exhibition the Mearns collection from cliff dwellings in the Verde valley, Arizona, which is one of the first made in this region. Recent explorations carried on under the auspices of the Museum have given it an interesting series of objects from the village sites and burial places of the Ohio valley. A small portion of the famous Squier and Davis collection from the mounds of Ohio was acquired by the Museum some years ago and is shown in the Ohio valley exhibit. The Jones collection from the Southern States is quite complete and many of the specimens were figured by Mr. Jones in his well-known work on the Southern Indians. A small collection from New York State and the material obtained on Staten Island at a burial place at Tottenville will interest those who are studying the Indian remains in the vicinity of New York. The Chenoweth and J. Bradley James collections from New York City are also shown. California and the West are represented by the Terry collection. During the year the Museum has been carrying on a thorough exploration near Trenton, N. J., in order to secure an authentic collection from this most important region in relation to the very early occupation of the Atlantic coast by man. Many specimens have been obtained during this exploration, but they cannot be exhibited until the new halls are ready. Owing to lack of space many other interesting objects and collections are in storage, awaiting the completion of the new wing.

On the walls of the ground floor of the main building is the well-known collection of Charnay casts of prehistoric sculptures from ancient cities in Mexico and Central America, recently presented by the Duke of Loubat. Among these is the famous Tablet of the Cross from Palenque.

THE INFLUENCE OF LIGHT UPON THE DISCHARGE OF ELECTRIFIED BODIES.

OF the many interesting phenomena that are continually being discovered in all branches of physical science, none are more important than those which point to the existence of hitherto unknown relationships between the different branches of physics; for it is by the careful study of such relationships that we may hope to proceed most rapidly with the further development of the science. This fact has been generally recognized by investigators, and the attempt to find new relations between apparently isolated classes of phenomena has led in the past to many important discoveries. The discovery by Oersted of the magnetic action of the current may be cited as one well known example.

In recent years the theory of light has gained greatly by the recognition of the close relationship between optical and electro-magnetic phenomena. The discovery by Faraday of the magnetic rotation of the plane of polarization afforded the first experimental proof of a relation between light and magnetism; the fact that certain dielectrics become doubly refracting when subjected to electrostatic stress (Kerr) indicated a connection between light and electrical phenomena; while the experi-

ments of Hertz upon electric waves have given to the electro-magnetic theory of light a standing almost equal to that of the most firmly established physical theories.

In 1887 still another class of electro-optical effects was discovered. It was then found that the passage of a spark between the terminals of an induction coil takes place more readily when the negative electrode is illuminated by ultra-violet light. The original observation, which was made by Hertz in the course of his experiments on electric waves, has since been abundantly confirmed. It appears that ultra-violet rays possess the power of assisting the discharge of negatively charged bodies, the magnitude of the effect being dependent upon the surrounding medium as well as upon the nature of the charged surface. Within the last few years Elster and Geitel have shown that the same effect is in some cases produced by the visible rays. The phenomenon has gained additional interest from the discovery by Lenard that a similar discharging power is possessed by the cathode rays, and this similiarity has been cited by Jaumann in an attempt to develop a theory of cathodic radiation. Still more recently it has been found that the effect is produced by the X-rays in yet more marked degree.

In spite of the comparatively short time that has elapsed since Hertz's original discovery, the literature of the subject is quite extensive. Strangely enough, only a few of the more important papers have been publshed in English, so that it is a matter of some inconvenience to learn just how far our knowledge of the phenomenon has progressed. For this reason, and in view of the evident importance of the subject, the writer has prepared the following account of the investigations which have thus far been published.*

* For a very brief account, see J. J. Thomson, Recent Researches in Electricity and Magnetism, p. 58–62.

DISCOVERY BY HERTZ.

1. As already mentioned, the phenomenon was first observed by Hertz* in 1887. The discovery was made during the progress of some of his earlier experiments upon electro-magnetic waves, and was purely accidental. In investigating the field near a Hertzian oscillator by means of an ordinary resonator some difficulty was met with in observing the faint sparks which occurred at the resonator. With the thought that observations could be more readily made in the dark, the resonator spark gap was surrounded by a box of non-conducting material; but it was found that the sparks were now fainter than before, and that the maximum sparking distance was noticeably diminished. On removing successively different parts of the box it appeared that only those portions lying between the primary and secondary spark were effective. The distance of these portions from the spark gap was immaterial; if the secondary spark was adjusted to its maximum length the interposition of a screen at any point between the primary and secondary spark caused the latter to cease.

2. At first thought it doubtless appeared natural to ascribe the effect to some electrostatic or electrodynamic action. Hertz was quickly convinced, however, that this could not be the true explanation, for the screening effect was produced as well by insulators, such as rubber, glass and paraffin, as by conductors. Again, although the phenomenon was first noticed when the sparks used were those of an oscillator and resonator, yet equality in the vibration periods of the two sparks was not essential. When two sparks were simultaneously produced by any other method the effect was still observed.

3. The most convenient means of study-

* Berliner Akademie, June 9, 1887. Wied. Ann. 31, 983.

ing the phenomenon was found to be by the use of two induction coils, whose primary circuits were placed in series with the same interruptor. During most of Hertz's observations the distance between the two coils was about 50 cm. The larger or 'active' spark was about 1 cm. long, while the length of the smaller or 'passive' spark was not far from 1 mm. Although especial attention was directed to the influence of the larger spark upon the smaller, it was proved conclusively that the action was reciprocal. The maximum sparking distance of each spark was increased by the presence of the other.

4. Making use of this apparatus Hertz investigated first the influence of changes in the character of the active spark, and found that the effectiveness of the latter was independent of its form. The spark could take place between spheres, or between points; could be short and straight, or long and zigzag; could be brilliantly white, or violet and almost invisible. In all cases its action upon the passive spark was practically the same. By screening successively different parts of the spark gap, it was shown that all portions of the active spark participated equally in the effect. A change in the metal of which the electrodes were made was also without noticeable influence.

5. On the other hand, the sensitiveness of the passive spark appeared to depend greatly on its character. Long zigzag sparks between points were scarcely affected at all by the presence of the active spark. The influence of the latter was best shown in the case of short sparks (1 mm. long) between brightly polished spheres of about 5 or 10 mm. diameter. Different parts of the passive spark appeared to be sensitive to the effect in different degrees. By screening various portions of the spark gap it was found that the effect was much greater when the negative pole was exposed. Hertz was unable to make sure, however, that the action occurred *exclusively* at the negative terminal.

6. A noticeable gain in sensitiveness was obtained by reducing the air pressure at the passive spark, a maximum being reached at about 100 mm. Only slight differences were observed when other gases were substituted for air.

7. Most substances, when used as screens, were found to destroy the effect. Some, however, were in greater or less degree transparent. The following is a partial list of the materials tested by Hertz:

Opaque.—Metals, even in extremely thin sheets; paraffin, sealing wax, rosin, rubber; glass, porcelain, wood, paper, ivory, leather, mica, most crystals; liquid paraffin, benzol, petroleum, liquid CO_2, strongly colored solutions, as fuchsin; various salt solutions, especially the copper and iron salts.

Partially transparent.—Sugar crystals, alum, calcite, rock salt.

Transparent.—Quartz, even in thick pieces, water, sulphuric acid, alcohol, ether.

A number of gases were tested, and in some cases (*e. g.*, burning gas) were found to be somewhat opaque.

8. By changing the relative positions of the two spark gaps it was shown that the effect proceeded from the active spark in all directions and in straight lines. The shadow cast by a screen was sharply defined; on gradually sliding a screen between the two sparks the effects ceased at once when the passive spark passed within the geometrical shadow. Reflection occurred at most surfaces in the same manner as with light. The rays also suffered refraction, being bent out of their course *more* than light rays. By using a prism of quartz it was found that the active rays lie far beyond the extreme violet of the visible spectrum. Attempts to obtain phenomena analogous to double refraction were unsuccessful.

9. A consideration of the results above described led Hertz to the conclusion that the effect must be due to the ultra-violet rays given out by the active spark. He therefore tried the effect of other sources of light, and found that all sources whose spectra are rich in ultra-violet rays produced an increase in the maximum sparking distance of the passive spark. Noticeable effects could be observed with the magnesium light even at considerable distances. The lime light was somewhat less active, while flames, such as burning gas, benzine, alcohol, CS_2, and others, had only a slight influence. No action could be observed with sunlight.

10. A photographic study of the spectra of the lights used showed not merely that the active rays are beyond the visible region, but that they lie at the extreme end of the photographic spectrum. By far the best source for these experiments appeared to be the electric arc. Most of the experiments already described were repeated by the use of the arc light with complete success.

EARLIER EXPERIMENTS OF WIEDEMANN AND EBERT, AND HALLWACHS.

The discovery of Hertz seems to have attracted immediate attention. Early in 1888, only a few months after the publica- of Hertz's work, two articles on the subject appeared simultaneously in Wiedemann's Annalen.

11. One of these articles, by Wiedemann and Ebert,* described experiments similar in character to those of Hertz, but performed with somewhat different apparatus. In place of the induction coil a Holtz machine was used. This proved to be more convenient, as well as more certain in its action. Ultra-violet rays were furnished by an arc lamp. The spark gap was enclosed in a glass tube containing a quartz window, so that experiments could be conveniently performed with different gases and at different pressures. The terminals were platinum spheres 3 mm. in diameter. A convenient means of measuring the effect was furnished by a second spark gap in parallel with the one studied, but screened from the rays of the arc. This could be adjusted until sparks passed across it rather than at the passive spark gap; the change required in this adjustment when the passive spark was illuminated then gave a measure of the effect produced by the rays. With this apparatus the more important experiments of Hertz were repeated, and his results confirmed.

12. Wiedemann and Ebert next investigated the following question: Do the ultra-violet rays merely assist the commencement of sparking, or is the action a continuous one? A Geissler tube placed in series with the active spark showed that the effect was continuous. When the spark was illuminated the Geissler discharge had all the characteristics that are possessed by such discharges when the tube is directly connected with the machine, *i. e.*, the illuminated spark gap acted much as a continuous conductor. As soon as the rays from the arc were cut off, the discharge became discontinuous, such as is usually observed when the connection to the machine contains a gap. A telephone placed in series with the spark gap gave a noticeably higher tone when the gap was illuminated. It thus appears that ultra-violet rays reduce the resistance offered by the spark gap to a disruptive discharge, and that this action continues as long as the illumination lasts.

13. To investigate what part of the arc is most effective in producing the rays needed, an image of the arc was thrown on the passive gap by means of a quartz lens. The effect was found to be greatest when the rays came from the positive carbon.

* Wied. Ann. 33, p. 240, 1888. Abstract in Phil. Mag. 25, p. 162.

This is in contradiction to the conclusion of Hertz, who found that the most active rays are from the arc itself.

14. Illumination of the positive terminal, or of the spark gap between the two terminals, was absolutely without effect. In order to increase the sparking distance the ultra-violet rays must fall upon the brightly polished *negative* terminal.

15. On experimenting at different air pressures it was found that the greatest effect was obtained at a pressure of about 35 cm. The results obtained with ordinary air, and with air that had been carefully dried, were practically identical. The phenomenon was also observed when the spark took place in hydrogen, the results being only slightly different from those in air. In carbon dioxide, however, the sensitiveness of the spark was noticeably increased. Other rays, also, in addition to the extreme ultra-violet, were found to be effective. "With CO_2 the active rays lie between the lines G and K of the visible spectrum." The influence of these rays could also be observed when the spark occurred in air, but in much less degree.

16. Wiedemann and Ebert give a brief discussion of a possible theory of the action based upon 'absorption by the gases condensed upon the electrodes.' This is supposed to facilitate the formation of cathode rays by a process analogous to resonance.

17. A paper by Hallwachs,* which appeared at the same time as that of Wiedemann and Ebert, describes work along a somewhat different line, and indicates the distinct gain which may result from the removal of unessential and complicating conditions. In attempting to reduce the experiments of Hertz to a simpler form, Hallwachs was led to believe that the effect was due to an increased tendency for the discharge of negative electricity, resulting in some way from the action of ultra-violet rays. Such an effect, he argued, might be present even when no spark discharge occurred. The spark gap was therefore dispensed with. A disk of polished zinc, 8 cm. in diameter, was suspended from an insulated support and connected with a gold-leaf electroscope. The two were then charged negatively. When the zinc plate was exposed to rays from an arc lamp its charge was found to be rapidly dissipated. During this experiment the electroscope itself was screened from the rays of the lamp, while in front of the zinc plate was placed a large zinc screen containing a window of gypsum. This substance was found to absorb the rays only slightly.

18. The effect was observed only when the plate was *negatively* charged.

19. Hallwachs was able to show that the active rays are *absorbed*, *reflected* and *refracted* in the same manner as had been determined by Hertz. Everything seemed to show that the increased rapidity of discharge observed with negatively charged zinc was merely another manifestation of the Hertz effect. The fact that the extreme ultra-violet rays are most effective was definitely proven.

20. It was by no means evident in the case of Hallwachs' first experiment whether the action occurred at the charged surface or in the surrounding medium. To test this point two plates were set up parallel to one another and at a distance of 3 cm. apart. Each was charged negatively and connected with an electroscope. When the rays passed between the plates and parallel to the surface scarcely any effect was observed. But if the plates were turned, so that one of them received rays from the lamp, its charge immediately began to fall. It therefore appears that the action occurs at the charged surface itself, and that if the medium exerts any influence it is of only secondary importance. An experiment of Bichat,* who

* Wied. Ann. 33, p. 301, 1888.

* C. R. 107, p. 557, 1888. Wiedemann's Beiblätter 13, 39.

lluminated the *interior* surface of a negatively charged hollow cylinder without observing any effect, confirms this view.

21. Since the effect is produced at the surface, it should depend upon the character of the surface. A well polished surface was, in fact, found to be from 40 to 50 times as sensitive as one that was rough or oxydized. With iron the effect was less marked than with zinc. With aluminum it was *more* marked.

DEVELOPMENT OF A POSITIVE CHARGE BY ILLUMINATION. WORK OF HALLWACHS AND RIGHI.

22. At the close of the article just referred to, Hallwachs mentions experiments indicating that the discharge of negative electricity may occur, under the influence of ultra-violet rays, even from a neutral body. In a later article* these experiments are described somewhat more at length. A polished metal disk was suspended within a metallic box and connected with an electrometer. When illuminated by rays from an arc lamp 45 cm. distant it was found to acquire a positive charge. The maximum potential reached was about $\frac{1}{2}$ volt for aluminium, 1 volt for brass, and a little more than 1 volt for zinc. The metal screen surrounding the disk was of rusty iron; this being chosen so that the contact potential difference between screen and disk should have a tendency to charge the former negatively. Otherwise the results obtained might be misleading. In order to prevent direct electrostatic induction from the lamp, the gypsum window through which the rays came was covered with wire gauze. All action ceased upon the interposition of a sheet of mica.

23. Hallwachs' article, which was quite brief, was followed by a note in the Comptes Rendus, by Bichat,† whose results are, to say the least, striking. Bichat's experiments were made with growing plants placed upon insulating supports and illuminated. With the exception of the geranium, all the plants tested were found to acquire a negative charge, with a maximum potential of 7–8 volts. This phase of the subject does not appear to have been carried further either by Bichat or by others.

24. A more elaborate investigation of the effect of ultra-violet rays was undertaken by Righi* in the same year, the first results being published almost at the same time as the work of Hallwachs. Righi's arrangement of apparatus was as follows: A sheet of wire gauze, B, was set up parallel with a metal disk, A, and a short distance in front of the latter. A was connected to one pair of quadrants of an electrometer, B to the other and also to earth. The needle was charged to about 100 volts. Upon grounding A for an instant, insulating and illuminating with rays from an arc lamp, the electrometer showed a deflection. The final deflection was the same even when A had an initial charge. When the steady deflection was once reached a change in the relative position of A and B was without influence upon the deflection. Righi concluded from this that the metals were brought to the same potential by the action of the light. If this is true the steady deflection obtained as above described should be a measure of the contact E. M. F. between the metals.

25. Righi found that the electrometer deflection increased with increase in surface exposed, and with diminished distance from the arc lamp. An arc between carbon and zinc was found especially effective. Sunlight was without influence.

26. Upon combining several pairs (disk and gauze) by connecting the wire gauze

* Wied. Ann. 34, 731, 1888. Phil. Mag. 25, p. 78 (Abstract).

† C. R. 107, p. 557, 1888. Beibl. 13, p. 39.

* Rendiconti d. Accademia dei Lincei 6, p. 185, 1888. Beibl. 12, 286. Reprinted in the *Journal de Physique* 7, p. 153, 1888.

of one to the metal disk of the next, a battery, with increased E. M. F., was obtained. When plates were used without gauze in front, all metals were found to become charged to a gradually and continuously increasing positive potential.

27. Righi was at first of the opinion that those metals which are found least active when judged by the rate of dissipation of a negative charge when illuminated were found *most* active if judged by the positive charge acquired from a neutral condition.* For example, aluminum and zinc showed the most rapid loss of negative electricity under the action of ultra-violet rays, but gold and copper (originally neutral) became more strongly charged positively than either.† Still later observations by Righi appear, however, to contradict the results stated above.‡ A heavily lacquered plate was grounded and punctured with a large number of small holes, through which ultra-violet rays fell upon a parallel polished plate. The final steady potential of the latter (which was insulated) was measured for different distances between the plates. The surface density developed by illumination could then be computed. It was $\delta = 0.000116$ C. G. S., for carbon and $\delta = 0.000161$ for Al.§ Other metals showed a surface density lying between these limits. It appears, therefore, that the charge increases until a certain definite *density* is reached. This density depends upon the temperature, changing in the case of zinc, from .000146 at 24° to .000218 at 10°. In still another article Righi says|| "it is to be observed that the order" in which the metals stand with regard to taking a positive charge "is almost the same as that which indicates the rapidity with which they lose a negative charge under the influence of illumination."

28. Attempts were made to find some effect with positively charged bodies, but without success.

29. Not only metals, but also sulphur and black rubber, were found to become positively charged when illuminated.

PHOTO-ELECTRIC CURRENTS. WORK OF STOLETOW.

30. It was shown in 1888 by Stoletow* that under suitable conditions it was possible to obtain a *current* by the action of ultra-violet rays. A metal plate 22 cm. in diameter and a parallel sheet of wire gauze were illuminated by an arc lamp. The + pole of a battery was connected to the gauze and the − pole to the metal plate, a sensitive galvanometer being in circuit. Under these circumstances a current was obtained so long as the illumination continued. On reversing the battery connections the galvanometer showed only a small deflection.

31. The effect was increased by carefully cleaning the metal plate. The current was found to be proportional to the illuminated surface. On increasing the distance between plate and wire gauze the current diminished, the law being approximately expressed by the equation $i = E \div (a + bl)$ where l represents the distance between plate and gauze. The current was proportional to E up to 2 volts. Beyond that E. M. F. the current increased less rapidly than the E. M. F.

32. Stoletow found in later experiments,† however, that the current remained constant so long as $\frac{E}{l}$ was constant.‡ "The

* C. R. 107, p. 559, 1888. Beibl. 13, 40.

† l. c.

‡ R. Acc. dei Lincei 5, p. 331, 1889. Beibl. 13, 566.

§ Later observations led Righi to correct these values to .000116 and .000241 respectively. See Atti. del. R. Inst. Ven. 7, 1889. Beibl. 13, 976.

|| Ibid.

* C. R. 106, p. 1149, 1888. Beibl. 12, 605. Phil. Mag. 26, p. 317. (Abst.)

† C. R. 108, p. 1241. Beibl. 13, 902.

‡ This law does not hold exactly at low air pressures. See Stoletow, Jour. de Phys. 9, p. 471, 1890.

current is therefore a function of the density of the negative charge, or of the electric force acting upon the negative plate." A curve plotted with $\frac{E}{l}$ and i as abscissas and ordinates respectively resembles a curve of magnetization. If the plate and gauze are of different metals the contact E. M. F. between them must be subtracted from E in computing the current.

33. If the metal of which the gauze is made is positive with reference to the plate (*e. g.*, gauze of zinc, plate of copper silver-plated), a current may be obtained without any battery.* The current in this case corresponded to the contact E. M. F. between the two metals (*i. e.*, about 1 volt). This was tested by placing a Daniell cell in the circuit and observing the increase in current. The tendency of illumination appears to be to equalize the potentials of the two metals. By connecting the two to a condenser and discharging the latter after equilibrium has been reached, the contact E. M. F. of the metals can be measured.†

34. Al, Zn, and Pb placed in the arc increase the effect. Stoletow calls attention to the fact that these metals are quite strongly electro-positive, and have strong ultra-violet spectra.

35. The experiment of Stoletow was modified by Borgmann ‡ in such a way as to make the illumination intermittent. If the development of a current followed the illumination instantly it was thought that the intermittent character of the current could be detected by a telephone. Although an E. M. F. of about 120 volts was used, no sound could be heard. Borgmann concludes that the action does not occur at once, but requires a finite time.

36. Stoletow, however, opposed this view* and was of the opinion that the telephone was not sufficiently sensitive to detect the sound. He rotated a disk of cardboard, containing 16 openings, in the path of the rays, while a commutator on the shaft (containing 16 segments) cut out the galvanometer and threw in an equivalent resistance 16 times each revolution. When the brushes were set for a maximum effect the galvanometer was found to be unaffected by changes in speed. Stoletow estimates, therefore, that the actinic current must be set up within $\frac{1}{1000}$ sec. after the beginning of the illumination. In this same paper Stoletow describes experiments with a sectored disk, which was rotated in in the path of the ultra-violet rays in such a manner as to diminish their intensity one-half. Under these circumstances the actino-electric current was also reduced one-half for all speeds of rotation.†

PHOTO-ELECTRIC EFFECTS PROBABLY DUE TO CONVECTION: WORK OF RIGHI, LENARD AND WOLF, HOOR, ETC.

Early in his investigations Righi came to the conclusion that the effects observed were due to a sort of electric convection, which for some reason was accelerated by ultra-violet rays. This conclusion was justified by the following experiments:‡

37. A rod carrying a mirror was mounted in a horizontal position inside a glass box by a delicate bifilar suspension. Thin sheets of Al were fastened to each end, and one of them was charged negatively by being connected with a dry battery. On illumina-

* Stoletow, C. R. 106, p. 1151. Beibl. 12, 605.

† Righi has followed up this aspect of the subject at some length. (Accad. dei Lincei, 5, 860. Beibl., 14, 69.) It was found that the contact P. D. depended in many cases upon the gas, and in some cases the direction of the E. M. F. could be reversed by changing from air to burning gas.

‡ C. R. 108, p, 733. Beibl. 13, 565. See also Phil. Mag. 26, p. 272.

* C. R. 108, p. 1241. Beibl. 13, 902. For resumé of Stoletow's work see also Phil. Mag 30, p. 437.

† l. c., p. 1242.

‡ Accad. dei Lincei 4, p. 6, 1888. Beibl. 12, 721. See also C. R. 107, p. 559, for brief statement of these results.

ting this sheet (through a gypsum window) with rays from an arc light, the system was deflected. The charged sheet seemed to be driven away from the light rays. This may be explained as due to the reaction from the electrified particles, which, under the influence of the ultraviolet rays, are being driven away from the surface. When the illuminated sheet was charged positively, or grounded, no effect was noticed.

38. Returning to the apparatus first used (metal disk and parallel wire gauze) an insulated plate of gypsum was placed between disk and gauze, and was observed to become negatively charged on the side nearest the Zn plate. If two plates of gypsum are used, only that nearest the Zn plate is charged. These results are well explained on the hypothesis of electric convection.

39. It was found that the charged particles producing the convection discharge travel along the lines of force of the field. (Suggested first by Hallwachs.) To prove this a vertical zinc cylinder was charged by a dry battery and placed near a large vertical zinc plate, the latter being grounded. The shape of the lines of force of such a system is known. With the exception of a narrow vertical strip the cylinder was lacquered, previous experiments having shown that a coating of lacquer prevents all action from ultra-violet rays. On illumination the convection discharge, if there is one, could therefore only take place from the unlacquered portion of the surface. If the electrified particles traveled along the lines of force it would be possible to predict the position at which they would reach the grounded plate. This was done, and a small insulated piece of zinc placed at the position computed was found to become negatively charged, while if at a different point it was unaffected.

40. In 1890 Righi* began experiments upon 'photo-electric convention,' etc. at low air pressures (going as low as .001 mm.). It was found that at ordinary pressures the electrified particles proceeded along lines of force, as shown earlier. But as the pressure was reduced there was a tendency for the paths of the particles to deviate more and more from the lines of force and to become more nearly coincident with the normal to the illuminated surface. In the course of these experiments it was found that the maximum positive surface density acquired by an unelectrified body when illuminated increases continuously with diminishing pressure. On the other hand, the rate of dissipation from a negatively charged surface increases to a maximum as the pressure is reduced and then diminishes. Righi concludes that the development of a positive charge, and the dissipation of a negative one, are different phenomena.

Numerous experiments by Stoletow* on the effect of diminished pressure upon the actino-electric current can merely be referred to. They seem in the main to confirm Righi's observations.

41. Observations by Bichat and Blondlot† appear at first to be in confirmation of the hypothesis of Righi that the discharge takes place by convection. These observers used an apparatus like that of Righi, gauze and plate being of the same metal. On illumination the plate became positively charged to a potential of 3 to 4 volts. If a draft of air is blown upon the plate, either by fanning or by allowing compressed air to escape against the plate, the potential was increased six or eight times. It would seem that this might be explained by convection taking place more readily under the action of the draft. Further experiments show, however, that the explanation is not so simple.

*Acc. dei Lincei 6, p. 81. Acc. di Bologna 10, p. 85. Beibl. 14, p. 1167.

* Journ de Phys. 9, 468. Beibl. 15, 233.

† C. R. 107, p. 29, 1888. Beibl. 13, 38.

42. The gauze was next connected with the pole of a battery (2 volts), the plate being at first grounded, so that it took a charge by induction, and then connected to the electrometer. When illuminated the plate became negatively charged, *i. e.*, lost electricity. (why?) But on blowing against the plate the deflection of the electrometer was reversed, and the plate became strongly positive. Blowing on the plate does not therefore merely take away the statical charge, regardless of sign.

43. If the gauze and plate are connected through a galvanometer without any battery, no current results from illumination alone. But when air is blown against the plate (with illumination) a considerable current flows. Without illumination no effect can be noticed on blowing.

The authors believe that the effects are in part due to the fact that there is a contact P. D. between metal and air, the latter being positive.*

44. Later in the same year Bichat† was led by other observations to believe that the negative discharge was due to convection. An apparatus similar to that of Righi,‡ which had been used in 1887 apparently without knowledge of any effect from illumination,§ was found to rotate more strongly under the influence of ultra-violet rays.

45. The hypothesis of the negative discharge being due to convection received the strongest confirmation from observation by Lenard and Wolf.|| Their results, however, contradict Righi's view in some particulars. In assuming the existence of convection Righi was of the opinion that the *air particles* became charged at the surface of the body and were then repelled.¶ This action would continue until a certain positive potential was reached, whereupon the attraction between the positive body and the negative particles would bring about a condition of equilibrium.

46. Lenard and Wolf urged in objection to this view that it is impossible for the particles of a gas to become charged; dust may receive a charge, but not gaseous molecules.* They therefore think that the cherge must be carried away by particles of the body itself, these being shaken loose in some way by the ultra-violet rays. They experimented first with thin gold leaf, silver and copper foil, etc., hoping to detect the loss of particles by some change in the optical transmitting power. After an exposure of some 50 hours to rays from an arc light the surface was found to be roughened at all points not screened from the rays. By interposing obstacles sharp shadows were cast, as shown by the roughening. No change could be noticed, however, by transmitted light. Any object which is opaque to ultra-violet rays (*e. g.*, glass) was capable of producing a shadow.

47. Being convinced by these experiments that particles were actually sent off under the influence of ultra-violet rays, the authors next attempted to observe the course of the particles after leaving the body. As a source of light the spark from an induction coil was usually employed. The arc lamp was also used with Zn in place of one carbon. The relative values of these lights in producing the negative discharge are shown by the observations described below:

A polished zinc disk 8 cm. in diameter was set up 30 cm. from the source of light, connected with a gold leaf electroscope, and charged to 1000 volts. The time required for the potential to fall to 200 volts was found to be

*For fuller statement of explanation see article.

†C. R. 107, p. 557. Beibl. 13, 39.

‡See § 37.

§C. R. 104, p. 1786. Beibl. 11, 716.

|| Weid. Ann. 37, p. 443, 1889.

¶ C. R. 107, p. 559, 1888.

* In this connection see *Nahrwold*, Wied. Ann. 31, p. 448; also J. J. Thomson, Recent Researches in Electricity and Magnetism, p. 53.

For ordinary arc.....17.2 sec.
Arc between Zn and C..... 2.3 "
Induction coil spark .....10.7 "

An uncharged Zn or Cn plate 30 to 40 cm. from the spark discharge became strongly charged positively within a few seconds.

48. For detecting the dust developed by the ultra-violet rays a glass vessel was prepared containing a quartz window. The vessel was filled under pressure with carefully filtered air. A dish of water within the vessel kept the air nearly saturated with water vapor. On allowing the air to expand suddenly dust could be detected, if present, by the fog resulting from moisture condensed on the dustparticles. By proper precautions air could be obtained dust free. But when ultra-violet rays had passed through the quartz window for about ten minutes the presence of dust could always be detected, even when no metal was within the vessel. The authors came to the conclusion that quartz itself gives off particles under the action of ultra-violet rays.

49. The use of the glass vessel in which the body to be tested was to have been placed was therefore abandoned. A jet of steam was then used to detect dust. The arrangement of apparatus is shown in the figure. A quartz lens L was placed in an opening in a grounded metal screen, and condensed the rays from the source upon the metal plate, M. Dust particles from the lens were prevented from reaching the steam jet, J, by a glass screen, S. The plate M was first carefully freed from adhering dust. Preliminary tests showed that the steam jet itself exerted no discharging action. When the zinc plate M was negatively charged, a strong dust reaction was obtained on illuminating it. The dust first showed itself in that part of the jet nearest the plate, and gradually extended. The effect was stopped by glass or mica placed in the path of the rays. No dust reaction was detected when the Zn was grounded.

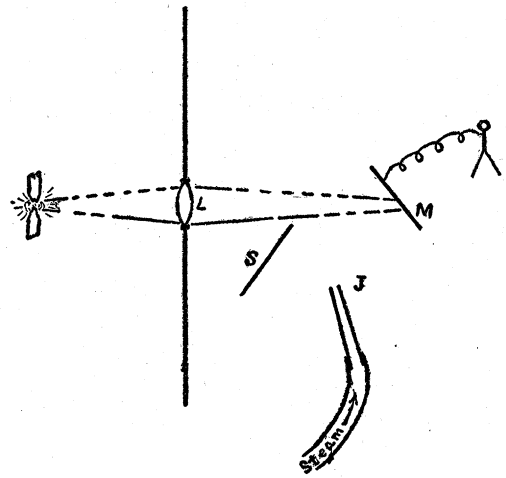

FIG. 1.

When M was charged positively there was also no effect. A potential as low as 300 volts (negative) was sufficient to enable the dust to be detected.

50. Various other metals were tested in in the same way and showed the dust reaction in different degrees. They are arranged below in descending scale, Ag being least sensitive:

Zn, Hg, Pt, Brass, Cu, Sn, Pb, Fe, Au, Ag.

51. With a positive charge no effect was observed in any case.

52. With a very sensitive steam jet the dust could also be observed from unelectrified metals, being best seen with copper.

53. Several liquids were tested, filter paper being soaked in the liquid to be investigated, and then charged. Fuchsin and Methylviolet showed the effect; water not at all. These liquids were tested also as to the influence of ultra-violet rays in producing negative discharge.* Water was quite inactive, while the other two liquids

* Liquid surfaces had previously been investigated to some extent by Stoletow [C. R. 106, p. 1593] and by Wiedemann and Ebert. [Wied. Ann. 35, p. 211.] See below.

showed themselves about $\frac{1}{8}$ as sensitive as zinc. It appears therefore that the liquids which give a dust reaction are the same that show an increased rapidity of discharge of negative electricity.

54. Further confirmation of the hypothesis of convection is given by the observations of Hoor.* His article contains also a discussion of some of the explanations of the phenomena that might be suggested: *e. g.*, (1) Electrostatic action from the arc light; (2) material particles sent out by the arc; (3) change in the conductivity of the medium (air) in which the body is placed; (4) change in the surface of the illuminated conductor by a transformation of light energy into electrical energy; (5) convection, under the influence of illumination. Rather obvious experimental reasons are given for discarding 1, 2,† and 3, and Hoor prefers to adopt the 5th. He is, however, inclined to accept the suggestion of Wiedemann and Ebert ‡ that the layer of gas condensed upon the surface plays an important part in the phenomenon. Particles of gas from this layer he thinks become charged, and, under the influence of ultra-violet rays, escape. Several experiments seem to show that any influence which tends to remove the layer of condensed gas diminishes the sensitiveness of the surface.

55. For example,§ a plate of either glass or gypsum laid upon the surface of a zinc disk prevented the dissipation of a negative charge by illumination. (Convection prevented.) The zinc plate remained inactive for a short time after the removal of the glass,* but became sensitive again either on resting 5 or 10 minutes, or by repolishing. (Surface gas layer removed by contact with glass, etc., on account of the greater attraction of the latter. A new layer condenses gradually.) (3.) A clean zinc plate was found to lose its sensitiveness after being covered for 3 hours with powdered charcoal. (Condensed gases absorbed by the charcoal.) (4.) A plate is rendered inactive by heating to 55° with a Bunsen burner,† but becomes sensitive again by cooling. (Gas layer dissipated by flame.) (5.) A plate covered with a thin film of glycerine is insensitive. (6.) After a plate has been illuminated for some time its sensitiveness diminishes, but increases again after a rest.

56. Righi at first held the same view as Wiedemann and Ebert and Hoor in regard to the importance of the layer of condensed gas.‡ Later he came to the conclusion that the condensed gases were without influence.§ He detected the alteration (roughening) of the surface under the action of ultra-violet rays independently of Lenard and Wolf, and investigated the shadows and figures produced at some length.|| In some cases the shadows cast by opaque bodies can be better shown by breathing on the surface.

57. Summing up the results in regard to convection, it appears that almost all observers agree in the belief that the negative charge is removed by convection of

*Repertorium der Physik 25, p. 91, 1889. Beibl. 13, 731.

†Hallwachs shows, however [Wied. Ann. 40, p. 332], that charged particles from the arc may cause trouble in some cases and that suitable precautions must be used.

‡This is practically the view first held by Righi.

§First paper, already referred to. Wied. Ann. 33, p. 240.

*Stoletow [C. R. 108, p. 1241. Beibl. 13, 902] contradicts this *absolutely*. He finds no diminution in sensitiveness even after the glass plate has remained in place 24 hours, provided that both glass and zinc are clean and dry.

†This is also contradicted by Stoletow (l. c.), who, however, used an air bath instead of a Bunsen burner.

‡Accad. dei Lincei 5, p. 331. Beibl. 13, 566, and 14, 68.

§Atti del Inst. Ven. 7, 1889. Beibl. 13, 976. Also Exner's Repertorium 25, p. 380.

|| Beibl. 13, 566; 13, 976; 14, 68.

some sort. Whether the particles which remove the charge come from the air, or from the condensed gaseous layer, or from the material of the body itself, is still in dispute. It appears to me that the mass of the evidence is in favor of the latter hypothesis. But the possibility that the phenomena may be complicated by electrolytic conduction in the medium surrounding the charged body,* must not be forgotten.

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(To be concluded.)

THE NORTH AMERICAN ORIGIN OF THE EDENTATES.†

THE explorations of the American Museum Paleontological party in the basin of the San Juan, New Mexico, during the past summer secured, among other important materials, the larger part of the anterior limb of *Psittacotherium multifragum* Cope, associated with the lower jaws and a number of the upper teeth. The specimen in question was found by the writer, and, with the exception of a few unimportant weathered fragments, was bedded in its original matrix, a soft, friable, reddish colored clay. The jaws and limb were not more than a foot apart, so that there can be very little doubt that they belong to one and the same individual.

It has been the custom of paleontologists to place the genus *Psittacotherium*, after Cope, in the Tillodontia, but it can now be shown that it not only does not belong in this group, but that together with *Hemiganus*, *Ectoganus and Stylinodon* forms a closely connected consecutive series ancestral to and leading directly to the Gravigrada, or ground sloths. A second series, composed of *Onychodectes* and *Conoryctes*, is clearly an allied group, which probably gave origin to the Armadillos.

These two series I have arranged under a new suborder for which I have proposed the name Ganodonta, and considered them as constituting a primitive division of the Edentata.

This suborder has been defined as follows: "Primitive Edentates characterized in the earlier forms by rooted teeth with divided fangs, having a more or less complete enamel investment; in the later forms by the teeth becoming hypsodont, rootless, of persistent growth, and by limitation of the enamel covering to vertical bands in progressive decrease. By the presence of incisors in both jaws, by a typical molar and premolar dentition, by a trituberculate molar crown, which disappeared early in life through wear, leaving the dentine exposed."

The evidence of the Edentate affinities of these forms is displayed most strikingly in the *Hemiganus*, *Psittacotherium*, *Ectoganus* and *Stylinodon* series in the following characters: (1) The enlarged teeth in the front of both upper and lower jaws can now be determined as being canines, and not incisors, as has formerly been supposed. In the earliest genus, *Hemiganus*, from the lower Puerco, the lower canine had already lost the enamel from its posterior face, while the crown of the upper canine is completely encased in enamel; the teeth were rooted, having divided fangs, and the crowns of the molars and premolars in the single specimen known are enamel-covered. (2) In the succeeding genus, *Psittacotherium*, from the upper Puerco, the superior canines had also lost the enamel from the posterior face, the roots of the lower molars and premolars were connate, while the roots of the upper molars were more or less divided into fangs. The crowns of the molars early lost

* In an early paper Arrhenius [W. A. 32, 545; 33, 638. Phil. Mag. 28, p. 75] suggested that the air conducted electrolytically under the influence of ultra-violet rays.

† Bull. Amer. Mus. Nat. Hist., Art. XVI., 1896.